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Citation

Puranam, Phanish, Ranjay Gulati, and Sourav Bhattacharya. "How Much to Make and How Much to Buy? Explaining Plural Sourcing Strategies." *Strategic Management Journal* (forthcoming).

Published Version

<http://onlinelibrary.wiley.com/doi/10.1002/smj.2063/abstract>

Permanent link

<http://nrs.harvard.edu/urn-3:HUL.InstRepos:10996796>

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HOW MUCH TO MAKE AND HOW MUCH TO BUY? AN ANALYSIS OF OPTIMAL PLURAL SOURCING STRATEGIES

How Much to Make and How Much to Buy?

P. Puranam, R. Gulati, and S. Bhattacharya

PHANISH PURANAM,^{1*} RANJAY GULATI,² and SOURAV BHATTACHARYA³

¹London Business School, University of London, London, U.K.

²Harvard Business School, Harvard University, Boston, Massachusetts, U.S.A.

³Department of Economics, University of Pittsburgh, Pittsburgh, Pennsylvania, U.S.A.

*Correspondence to: Phanish Puranam, London Business School, University of London, Regents Park, London, NW1 4SA, U.K. E-mail: ppuranam@london.edu

While many theories of the firm seek to explain when firms make rather than buy, in practice firms often make and buy the same input—they engage in plural sourcing. We argue that explaining the mix of external procurement and internal sourcing for the same input requires a consideration of complementarities across and constraints within modes of procurement. We create analytical foundations for making empirical predictions about when plural sourcing is likely to be optimal and why the optimal mix of internal and external sourcing may vary across situations. Our framework also

proves useful for assessing the possible estimation biases in transaction level make-or-buy studies arising from ignoring complementarities and constraints. Copyright © 2013 John Wiley & Sons, Ltd.

Keywords: plural sourcing; mixed procurement; firm boundaries; tapered integration; theory

Received 19 August 2009; Final revision received 14 August 2011

INTRODUCTION

Following the extremely productive research trajectory sparked by Coase's original insights, there is general consensus today that the boundaries of the firm matter—that making and buying are qualitatively distinct forms of governance and organization (Coase, 1937). Indeed, the make-or-buy problem has become central to theories that attempt to explain the nature, origin, and boundaries of the firm. Transaction cost economics, a leading theoretical perspective on these issues, specifies whether firms choose to make or buy a key input as a function of the need for investments specific to the transaction, uncertainty about contract parameters, and frequency of transactions (Williamson, 1991a, b). Other theorists, while offering different explanations for the choices between make and buy, such as superior coordination and knowledge transfer within firms (Conner and Prahalad, 1996; Grant, 1996; Gulati, Lawrence, and Puranam, 2005; Kogut and Zander, 1996), differences in production competence (Jacobides and Hitt, 2005; Jacobides and Winter, 2005), or information asymmetry and measurement costs (Barzel, 1982; Demsetz, 1988), nonetheless retain the discrete make-or-buy choice as the central empirical phenomenon to be explained.

Yet, firms often make *and* buy the same input (Bradach and Eccles, 1989; Harrigan, 1986). Such instances of plural sourcing—of a firm simultaneously using multiple modes of procurement for the same input—have been well documented across a number of settings. Firms in the auto industry often both make and buy the same components (Gulati *et al.*, 2005), as do those in the metal works (Parmigiani, 2007) and the fashion garments industries (Jacobides and Billinger, 2006). Firms are also known to rely simultaneously on their own as well as external distribution channels (Dutta, Bergen, and Heide, 1995; Heide, 2003), and combine chains of fully owned and franchised operations (Bradach, 1997; Lafontaine and Slade, 1997). While scholars increasingly recognize the existence of the plural governance form as well as agree broadly on the reasons for its existence (Argyres and Liebeskind, 1999; Jacobides and Billinger, 2006; Parmigiani, 2007; Parmigiani and Mitchell, 2009;

Rothaermel, Hitt, and Jobe, 2006), in this paper we will use a formal optimization model to tackle two specific issues that have remain unexplored.

First, we develop arguments to explain specific *plural sourcing strategies*—how much firms choose to make vs. how much they choose to buy. Perhaps surprisingly, arguments for why a firm might be better off making than buying, as well as arguments that explain the benefits of both making and buying, do not on their own shed much light on *how much* firms make and buy. Through our analysis, we show that to explain plural sourcing strategies—how much of their requirements firms meet through in-house production as opposed to external purchase—we need to account for nonlinearities in the differential advantages/disadvantages of making and buying.

Second, we also analyze the possible *estimation biases* that may arise in studies of “make or buy” when scholars ignore plural sourcing and its antecedents such as complementarities and constraints. Empirical studies of the make or buy problem often feature a dichotomous characterization of a procurement decision as make or buy based on some arbitrary cut-off (e.g., more than 80 percent bought is defined as “buy” in the classic study of outsourcing in the auto industry by Monteverde and Teece, 1982), reflecting the empirical reality that firms can and do choose both modes of transacting simultaneously. Our analysis provides an assessment of the nature of the biases that may result from such dichotomized measures.

It is useful to clarify at the outset the distinction between plural sourcing and what are often known as “hybrids”—organizational forms that are distinct from in-house procurement and arms length market relationships (Hennart, 1993; Powell, 1990; Williamson, 1991b). Hybrids are a mode of procurement that are different from either make or buy—they may not feature complete ownership, but may however be characterized by a degree of cooperation and coordination that is unusual in market relationships (Gulati *et al.*, 2005). They often embody greater authority and continuity of association than is found in market relationships, but also more reliance on prices than is typical for

firms (Bradach and Eccles, 1989; Williamson, 1991a). Hybrids are “mixed modes” of procurement in the sense that they display governance characteristics that appear to combine price and authority (Bradach and Eccles, 1989; Hennart, 1993).

However, plural sourcing refers to a different phenomenon—a mixing of modes in the sense that firms may simultaneously rely on pure hierarchy (internal procurement) as well as price (market contracts) for the same input. Thus, whereas hybrids refer to procurement of the *entire* volume from a single mode that exhibits mixed governance characteristics, plural sourcing refers to the splitting up of total volume being procured across multiple modes, each of which may be a pure governance mode. As we will argue in this paper, the rationale that motivates plural sourcing is quite distinct from that underlying the preference for hybrids over either making or buying. To keep our theorizing parsimonious, we will focus on plural forms that include simultaneously making and buying, though the analytical structure of our arguments would be identical if considering the following: **Q1**

WHY MAKE-OR-BUY THEORIES DO NOT EXPLAIN PLURAL SOURCING STRATEGIES

Consider a canonical representation of transaction cost arguments found in Williamson’s work (1991a). Figure 1 (based on Figure 1: 284 in Williamson’s 1991 paper in the *Administrative Science Quarterly*) shows governance costs for a transaction when it is conducted within markets (M) and hierarchies (H), respectively, as a function of the extent of asset specificity (k) involved. This is a **Q2** graphical version of the “comparative cost/benefit” analysis first indicated by Coase (1937), and developed subsequently by Williamson (1985; 1991b). The figure shows that the governance costs are lower for markets than hierarchies at low levels of asset specificity, but higher in markets than hierarchies for high levels of asset specificity, implicitly holding the benefits from the exchange constant.

(INSERT FIGURE 1 NEAR HERE)

What is noteworthy is that the marginal (per unit) governance costs shown in Figure 1 are volume independent—they describe the relative costs of markets, hierarchies, and hybrids whether a single unit of a good is being exchanged or a million units. If it is cheaper to use markets for the first unit of a good being procured, so it is for the millionth unit—within the logical framework represented by the figure; there is no reason why firms should procure some fraction of their requirement for a good (with a certain level of asset specificity) from the market and make the rest internally. This picture makes clear that the traditional comparative cost/benefit analysis of transaction cost economics does not accommodate the possibility of plural sourcing—quite naturally, as that is not the emphasis of the theory.

Indeed, arguments from a transaction cost perspective suggest that many cases of apparent plural sourcing may turn out to be quite different things being procured through different modes. For instance, Williamson (1985: 96) argues that when firms appear to be both making and buying the same good, a closer examination should reveal that the internally produced good actually involves higher asset specificity—what appear identical are in fact heterogeneous transactions. The claim, therefore, is that what appears on the surface to be a case of a firm procuring the same component through make and buy is actually the firm procuring two distinct components, each being procured by the appropriate means.

An empirical illustration of this “transactional heterogeneity” argument can be found in a paper by He and Nickerson (2006), which examines why many interstate trucking companies engage in hiring their own drivers as well as relying on external drivers often for trips of comparable mileage and loads. The answer they propose is that not all load-miles are equal, thus suggesting that firms are not necessarily simultaneously making and buying the exact same thing. In the trucking industry, a key profitability driver is the avoidance of empty backhauls. Orders that originate and terminate at company depots are economically different from orders that do not—even if the weight and distance

are identical. Trucking companies therefore use their own drivers for orders of the former type, while outsourcing those of the latter type. Thus, in their paper once transactional heterogeneity is correctly accounted for, the “anomaly” of plural sourcing disappears (He and Nickerson, 2006).

We take a different perspective in this paper by offering a theoretical explanation for differences in the amounts that firms source internally or externally, on the assumption that they at least sometimes do engage in plural sourcing. Arguments about transactional heterogeneity notwithstanding, as we noted in the Introduction, the documented instances of firms procuring nearly identical inputs from internal and external sources simultaneously are too numerous to be ignored (Harrigan, 1986; Bradach and Eccles, 1989; Parmigiani, 2007; Gulati *et al.*, 2005; Jacobides and Billinger, 2006). Put differently, how frequently plural sourcing occurs is an empirical question; however, as long as it does occur at all, there is potential value to a theory that explains how firms optimally choose how much to make and how much to buy. This raises an obvious question—can we simply extend current theories about whether firms make or buy to explain how much firms make and buy?

It is not feasible to apply a logic that explains if an input is either made or bought to the question of *how much* is made and *how much* is bought without modifying and extending the logic significantly. For instance, the standard comparative cost logic of transaction cost economics cannot explain why some proportion of a good is made and some proportion simultaneously bought; it only allows for a prediction of the conditions under which all or none of it is bought (or made). Nor is it possible to invoke measurement/judgment errors to justify predictions about the extent of internal procurement, without additional assumptions. For instance, it might appear plausible to argue that when a firm makes 75 or 80 percent of its requirement for an input, it can be interpreted to mean that the firm is in fact making 100 percent internally and the 20 percent represents errors of measurement or judgment on the part of management (Monteverde and Teece, 1982; Poppo and Zenger, 1998).

However, this leaves unanswered the question of why the extent of the error should be correlated inversely with transactional hazards.

Another approach sometimes taken by scholars to explain plural sourcing is to suggest that plural sourcing occurs when firms are just indifferent between making and buying (Parmigiani, 2007). This situation occurs in Figure 1 at asset specificity level of k^* , at which point firms are likely to be indifferent between the two discrete choices of make or buy. One can also imagine scenarios where the effects of different transactional attributes cancel out the advantages of both market and hierarchical procurement so that a situation of indifference prevails. For instance, the level of asset specificity may be high but so may be the cost of bureaucracy borne if the transaction is integrated, making firms indifferent between their discrete choices. The “indifference hypothesis” can explain why, in a cross section of firms engaging in identical transactions, some choose to make and others to buy. Further, this indifference hypothesis may also help explain hybrids—if the hybrid offers a governance cost advantage over either market or hierarchy when transactional hazards and costs of bureaucracy are finely balanced. However, it cannot explain why any given firm should do both, nor the proportion it may source from each mode.

A model of optimal plural sourcing strategies

We formulate a full information optimization model in which a decision maker chooses how to arrange for the total supply of an input: how much to make and how much to buy, given a set of exogenous parameters that might, however, reflect the consequences of limited information and bounded rationality. This approach closely adheres to the approach of Oliver Williamson (1990, 2000), who describes “farsighted contracting” that allows a rational consideration of the costs and benefits of different governance modes, independent of the fact that these costs and benefits partly arise from limited rationality. Thus: “Economic actors have the ability to look ahead, discern problems and prospects and factor these back into the organizational/contractual design” (Williamson, 1990:

226). For instance, hierarchy is superior to contractual relationships when one anticipates the *need* for future adaptation whose *details* cannot be fully anticipated. In the same spirit, the decision maker in our model makes a rational decision based on knowledge of certain parameters, but the value of these parameters—such as transactional hazards, complementarities and constraints—may reflect the limited rationality of the decision maker. We model how complementarities and constraints influence firms’ decisions to simultaneously make *and* buy (see Table 1 for an overview of complementarities and constraints in procurement). In contrast to traditional comparative costs/benefit arguments (e.g., the benefits of internalization in the presence of transaction hazards), which explain whether firms make or buy, complementarities and constraints explain why firms might choose to do a bit of both (i.e., plural source), as well as variations across firms in how much they make and buy.

(INSERT TABLE 1 NEAR HERE)

Standard formulations of theories that explain the make-or-buy decision by invoking the comparative cost/benefit logic can explain which of the two corner solutions (all make or all buy) would be adopted—the logic is one of forces that “push towards the corners.” For instance, a net advantage in terms of governance costs in favor of make (for instance, because of asset specificity) would imply that firms make their entire requirements; a net disadvantage (for instance, due to extremely high costs of bureaucracy) would imply that firms choose to buy their entire requirements. Our goal is to propose a model that not only formalizes when firms engage in plural sourcing, but also specifies the optimal mix of how much they (should) make and how much they (should) buy.

The optimization problem we formulate to gain insight into plural sourcing can be written as

$\underset{x,y}{\text{Minimise}} C(x,y) \text{ s.t. } x + y = q > 0, x \geq 0, y \geq 0$. Here, x is the quantity of an input made in-house and y is the amount bought from an external source and $C(x,y)$ is the total cost of sourcing the input, which is to be minimized. We normalize $q = 1$ so that (x, y) become the proportions made and bought,

respectively. A measure of the extent of plural sourcing is then given by $\rho \in [0, 1/4] = x(1-x)$. This measure takes on high values when the split between internal and external procurement is equitable; when firms choose “all make” or “all buy,” the measure takes on its lowest values.

We write the total cost of sourcing as

$$C(x, y) = xc(x, y) + yp(x, y), \quad (1)$$

where the average cost of internal sourcing is $c(x, y)$ and the average price paid for external purchase is $p(x, y)$. These are assumed to take the following forms¹:

$$c(x, y) = (m - k_1 y + \frac{i}{2} x) \quad (2)$$

$$p(x, y) = (b - k_2 x + \frac{e}{2} y) \quad (3)$$

Thus, the total cost need not be linear in production or purchase volume. We explain in the Equations (2 and (3 in detail below, with each parameter dealt with separately. The parameters can broadly be classified into those that capture volume independent marginal costs of the input, and those that capture volume dependent marginal costs.²

The effect of transactional hazards

¹We also outline a more general version of the model in the Technical Appendix to the paper.

²We show in the Technical Appendix that additive separability of these two kinds of costs, as assumed in Equations (2 and (3, is not critical to our results.

First, we capture the standard formulation of transaction cost economics arguments about the make or buy decision. The parameter $m(> 0)$ captures the volume independent component of the average cost of internally sourcing each unit. This includes both production costs as well as any relevant governance costs (e.g., the costs of bureaucracy). Similarly, the parameter $b(> 0)$ captures the volume independent component of the average price paid per unit for purchasing from an external supplier. Again, this includes both the exchange price as well as any relevant governance costs (e.g., the transaction costs of exchange with an external supplier). Thus, all else being equal, the existence of substantial transactional hazards and an advantage for internal over external sourcing would be captured by $b - m > 0$. Henceforth, we will refer to $\delta = b - m > 0$ as a measure of transactional hazards to ease exposition, while fully being aware that there are other reasons for $\delta > 0$ (for instance, lowered costs of internal sourcing due to superior coordination and knowledge transfer with an internal supplier; Kogut and Zander, 1996; Conner and Prahalad, 1996; Gulati *et al.*, 2005) as well as being open to the possibility of $\delta < 0$ (for instance, due to very high levels of bureaucratic costs or very high levels of scale economies, giving the advantage to specialist external suppliers in terms of production costs).

To set this back in the context of standard transaction cost reasoning, we could think about $\delta = b - m$ as capturing the difference in governance costs as shown in Figure 1 (which is itself based exactly on Figure 1: 284 in Williamson's 1991 paper in the *Administrative Science Quarterly*). As asset specificity—the key transaction hazard considered in transaction cost economics—increases, initially $\delta < 0$ but larger values of asset specificity result in $\delta > 0$, exactly as in Figure 1. Thus, the volume independent components of the marginal cost of sourcing in our model capture identical aspects of standard transaction cost arguments.

Complementarities across sourcing modes

The parameters $k_1, k_2 (> 0)$ capture complementarity effects between the two modes of sourcing. Complementarities refer to a situation in which the performance consequences of a choice depend on other choices (Milgrom and Roberts, 1990; Milgrom and Roberts, 1995). In formal terms, this is often expressed as the marginal value of one variable depending on the value of another variable (Milgrom and Roberts, 1990). The notion of complementarity recurs under various guises as “interdependence” (Thompson, 1967), “fit” (Drazin and van de Ven, 1985), or “synergies” (Markides and Williamson, 1996) in the literature on organizations and strategy (Milgrom and Roberts, 1995). In the context of plural sourcing, complementarity refers to the condition in which the marginal benefit of procuring a good from the market depends on the level of in-house sourcing, and vice versa. In the words of Bradach and Eccles (1989), “Transactions controlled by one mechanism are profoundly affected by the simultaneous use of an alternative mechanism.” We note that, by their nature, complementarities are systemic—the gains are most accurately assessed at the level of the “system” defined by the choices, rather than at the level of each individual choice (Milgrom and Roberts, 1995). Thus, complementarities between modes of obtaining an input could enhance the performance of the firm or, more precisely, the downstream business unit that engages in plural sourcing.

By definition, complementarity effects are volume dependent, in the sense that k_1 scales the reduction in the average costs of internal sourcing for every unit of external sourcing, and k_2 captures the reduction in average prices paid to external suppliers with every additional unit of internal sourcing. The mechanisms underlying such complementarity effects have been noted by several observers of sourcing strategies, and can be broadly classified into “incentive” and “knowledge” categories (also see Table 1).

The key mechanism underlying incentive complementarities is competition. By creating implicit or even explicit competition between internal and external units, the procuring firm enjoys the

benefits of stronger incentives acting on both kinds of suppliers. One of the earliest explanations for plural sourcing hinged on the incentive complementarity argument that if firms both made and bought an input, it gave them the ability to credibly threaten backward integration to their suppliers (Porter, 1980). Harrigan's work (1985, 1986) documented specific instances of this form of plural sourcing, adding texture to the concept of tapered integration described by Porter (1980). A related incentive-based advantage to plural sourcing is that internal sourcing can give firms superior insight into performance measurement and costs, enabling enhanced monitoring and measurement of their external suppliers (Dutta *et al.*, 1995; Harrigan, 1985, 1986; Heide, 2003). Equations

(2 and (3 also capture the intuition that increasing levels of sourcing in one mode increase both the credibility of the threat of replacing sourcing in the other mode as well as the effectiveness at monitoring it.

In contrast with incentive complementarities, knowledge complementarities refer to improvements in the competence of internal suppliers because of procurement from external suppliers and vice versa. Knowledge complementarities in procurement can arise whenever the knowledge generated in each mode of procurement is distinct from the knowledge generated in the other mode, but is usable in both (Sorensen and Sorenson, 2001). The mechanism underlying such complementarities is collaboration (not competition) between internal and external suppliers in order to create value for the procuring firm. Firms can benefit by their internal and external suppliers sharing their individually generated knowledge of improvements in production processes and technologies, thus enabling each other to enhance their efficacy and effectiveness.

It is, of course, critical that collaborative mechanisms exist for the exchange of knowledge between internal and external suppliers, as the movement of knowledge across the boundaries of the firm is not easy (Kogut and Zander, 1996). Bradach's analysis of plural forms in franchising underlines the importance of formal mutual learning processes for knowledge complementarities to be

exploited (Bradach, 1997). Despite the deep difficulties posed by knowledge transfer across firm boundaries, scholars have documented instances of firms effectively exchanging the knowledge underlying such performance improvements both within and between themselves (Dyer and Hatch, 2006; Dyer and Singh, 1998; Hatch and Dyer, 2004; Helper, MacDuffie, and Sabel, 2000). This suggests that knowledge complementarities can vary in their magnitude by setting rather than being all or nothing. They may also be more significant when the firm makes and procures from a hybrid structure, rather than makes and buys through a spot market transaction, as the organizational structures that enable the flow of knowledge are more likely in the latter than the former. In this case, “hybrid” replaces “buy” as the label of the second mode of procurement, but the rest of the analysis remains unchanged. As with incentive complementarities, it seems intuitive that the extent of knowledge produced in each mode that is valuable to the other should bear an increasing relationship to the volume procured in that mode, and this is captured in Equations

$$(2 \text{ and } (3.^3$$

A more subtle form of complementarity that mixes incentives and knowledge occurs through a process that has been described as “ratcheting” (Bradach, 1997). In situations where a firm engages in plural sourcing, it is often possible for it to use the performance achieved in one mode as the standard for the other. For instance, franchisee and company-owned fast food restaurants frequently benchmark their performance against each other. The effect goes beyond just the maintenance of current

³Since knowledge-based complementarities appear to rely on collaboration, whereas incentive complementarities arise from competition between internal and external suppliers, it is tempting to conclude that the two are mutually exclusive. Yet, there is sufficient evidence that relationships with suppliers tend to have elements of both competition and collaboration, so that it is possible for the two sources of complementarity to coexist (Helper, MacDuffie, and Sabel, 2000; Helper and Mudambi, 1996).

standards, to include a virtuous cycle of continuous improvement as internal and external supplier compete against the performance benchmarks established by the other (and inevitably overshoot).

In Table 1, we also offer some suggestions on how to empirically measure incentive and knowledge complementarities. We do not include transactional hazards in Table 1, as we have very well developed existing theories that elaborate on the concept, its effects and underlying mechanisms (i.e., hold-up), and operationalization (i.e., asset specificity). Incentive complementarities should be stronger when the measurement of production efforts or costs is difficult leading to reduced bargaining power for the downstream unit. Under these circumstances, a credible alternative supplier as well as a source of information on costs and optimal performance can prove very useful to the downstream unit in its dealings with both internal and external suppliers. Knowledge complementarities should be stronger for relatively novel production technologies—where much remains to be learned about optimal production. Having both internal and external units simultaneously learn how to refine and improve the use of the production technology can eventually benefit both, and ultimately the downstream unit as well.

It is worth noting that, analytically, the two complementarity parameters $k_1, k_2 (> 0)$ can be

treated equivalently in our analysis. To see this, note that $\frac{\partial^2 C}{\partial y \partial x} = -(k_1 + k_2) < 0$. Therefore, when our arguments do not require us to distinguish the strength of the complementarity arising from internal sourcing leading to reduction of average price or purchase leading to reduction of average internal procurement cost, we write $k_1 + k_2 = \theta$.

While much of the prior discussion of plural sourcing has been asymmetric in the sense that the emphasis was on the benefits of some internal sourcing for managing external suppliers (Porter, 1980; Harrigan, 1985), i.e., k_2 , more recently, researchers have explicitly recognized the complementarity can work both ways—participation in the external markets also helps to discipline the internal

provider, i.e., k_1 . “Placing an outside order, over and above the transactional and cost considerations can be seen as an investment that infuses the firm with discipline through its active participation in intermediate markets” (Jacobides and Billinger, 2006: 256). Indeed, the same argument can be made for the threat of backward integration—just as an internal supplier threaten vendors with backward integration, an external supplier can be the basis for a firm providing a credible threat to its internal unit with divestment and outsourcing in the event of poor performance. However, as our formulation clearly shows, the magnitude of the two effects need not be identical ($k_1 \neq k_2$).

It is useful to lay to rest a common misnomer at this point: that the existence of complementarities imply that plural sourcing will always involve an even split between internal and external sourcing. Consider, for instance, the arguments of Brusoni, Prencipe, and Pavitt (2001) about the knowledge complementarities between internal and external production for a systems integrator. While making 10 percent of the requirement of a product internally may enhance the value of the 90 percent bought from the market (because of complementarities such as transferring design requirements and improvements to the supplier and/or monitoring the supplier better), it does not seem reasonable to assume that systems integrator firms would make 50 percent internally in order to obtain these benefits. However, it is easy to show that the existence of complementarities does not necessarily imply a 50 percent split in volume across sourcing modes, once we factor in the basic transactional hazard logic. Assume that on a per unit basis, buying is superior to making because production assets are not specific, and costs of bureaucracy are significant ($\delta < 0$). Then, even if there are complementarities between making and buying arising from either knowledge or incentive considerations, there is a natural limit to how much the systems integrator firm will make to leverage these complementarities, because the gain from complementarities must be offset against the costs of sourcing more volume from the less efficient mode (on a per unit basis). In more technical terms,

while making and buying may be complementary, the marginal rate of technical substitution between the two may not be equal to one.

Constraints within sourcing modes

The parameters $i, e(> 0)$ capture scale constraints arising from increasing marginal costs to internal and external sourcing, respectively—these costs are assumed to be convex. Thus, i indicates the strength of the “limits to scale” constraint, so that ix is the increasing marginal cost of producing internally. Diseconomies of scale in production are a standard assumption in neoclassical economics, and underlie the upward sloping portions of long-run average cost curves (Pindyck and Rubinfeld, 1995). The source of these diseconomies often lies in the limits of managers and the organization (Coase, 1937; Simon, 1945; Arrow, 1974). Administrative limits to scale can arise from pure coordination failures as well as from motivation losses.

A dramatic illustration of scale diseconomies that arise purely from coordination complexity is provided in the experimental research on coordination games (Camerer, 2003). A series of studies have shown that in the weakest link game (a pure coordination game with symmetric equilibria that can be Pareto ranked), coordination failures increase dramatically with the size of the team playing the game (Weber *et al.*, 2001; Weber and Camerer, 2003). This is due to the combinatorial increase in the number of other players with whom one must share convergent expectations in order to select the efficient equilibrium.

The effects on motivation of increasing group size are also well known. The usage of flat wages (i.e., no pay for performance) is relatively common in firms (Williamson, 1991), and the motivational losses created by this can only be larger with larger scale. However, even pay for performance is not immune to problems; free riding is the tendency of individuals to shirk group activities, as their marginal returns are not large enough to offset their marginal costs of efforts. The marginal returns decrease with group size, so that free riding problems worsen with increasing size

(Holmstrom, 1982; Kollock, 1998). With increasing group size, each individual also bears greater risk as the outcome is increasingly determined by others whom that individual may have little control over, so that effective incentive intensity is reduced (Baker, 2002).

Another well-known source of diseconomies to scale arises from volume uncertainty coupled with costs of excess capacity (Porter, 1980; Harrigan, 1986). With fluctuations in demand, firms are exposed to periods of excess capacity if they choose to invest in production for peak demand (Pindyck and Rubinfeld, 1995). If the cost of this excess capacity is significant, then the firm may optimally choose to produce at lower scale (Balakrishnan and Wernerfelt, 1986).⁴ In our model, the larger i is, the more significant the diseconomies of scale that impose constraints on internal sourcing.

Similarly, the parameter e can be interpreted as indicating the strength of the “limits to scale” in external procurement, so that ex is the increasing marginal cost of purchasing externally. However, the increasing marginal costs of external purchase may not arise from the inability of suppliers to provide at larger volumes, but rather because of the increasing difficulty firms may face in terminating internal production. Barriers to exit may exist because of reputation or commitment lock-ins (Ghemawat, 1991). In effect, maintaining uneconomical in-house production may be necessary to sustain reputations or honor commitments made to various stakeholders (or even competitors). Employment contracts, public commitments, regulation, and pressures from unions may prevent firms from completely exiting production even when it is clearly more economical to procure from the market, with the level of resistance increasing with greater levels of outsourcing. More generally,

⁴This assumes that the firm cannot sell the intermediate good on the market; alternately, we could say that we assume the cyclicalities in demand facing the firm also affects other potential purchasers of the intermediate product.

constraint on a firm's governance choices arising from choices in prior periods is known as governance inseparability (Argyres and Liebeskind, 1999, 2002), and barriers to exit from internal production or limits to scaling internally because of prior commitments to external suppliers are instances of such inseparability. An additional reason for the increasing marginal costs of external procurement may be the coordination costs of dealing with multiple suppliers as the limits to scale of individual suppliers are reached.

Table 1 provides some suggestions on how one might operationalize both kinds of constraints: limits to scale and barriers to exit, through variables such as the size of an organization, the presence of strong unions, etc. As this table makes clear, these constraints and complementarities may indeed be shaped by corporate strategy decisions; they are assumed exogenous to the decision making we model in this paper, but we certainly do not intend to imply they are entirely exogenous to the firm. We note that there are other limits to scale and barriers to exit that may not, however, manifest themselves as increasing marginal costs of in-house production or external procurement. For instance, the simplest economic rationale for barriers to exit may arise when fixed costs take on the form of sunk investments. Under such circumstances, it may be rational to continue in-house production because the variable costs are lower than that of the average costs associated with procuring externally. However, this does not tell us what the ratio of internal to external production should be—as it only indicates a preference for in-house production. This rationale therefore falls into the class of explanations that help understand, at the transaction level, whether a particular transaction is conducted internally or externally—but not the proportions of internal and external procurement.

Analyzing optimal plural sourcing strategies

Solving for optimal levels of internal and external sourcing by minimizing total costs of sourcing (Equation (1), we obtain

$$x^* = \frac{e + (k_1 + k_2) + (b - m)}{e + i + 2(k_1 + k_2)} \quad (4)$$

$$y^* = 1 - x^* = \frac{i + (k_1 + k_2) - (b - m)}{e + i + 2(k_1 + k_2)} \quad (5)$$

We simplify notation by writing $(k_1 + k_2) = \theta$, $(b - m) = \delta$. Further, to ease exposition, we ignore for the moment differences in the *relative* magnitude of the two constraints—limits to scale and barriers to exit—and set $i = e = s$. While the two constraints appear to work in opposite ways (i.e., limit external vs. internal procurement) they both in fact serve to increase the tendency towards plural sourcing. Put differently, both are constraints on pure sourcing strategies, so that it is intuitive to combine both effects into one parameter.⁵ Thus, we have three variables: δ , the volume-independent net advantage of internal procurement, θ , a measure of complementarities, and s , a measure of constraints. We write our results in terms of these three parameters.

Simplifying Equation (5 in this way yields

$$x^* = \frac{1}{2} + \frac{\delta}{2(s + \theta)} \text{ and } y^* = 1 - x^* = \frac{1}{2} - \frac{\delta}{2(s + \theta)} \quad (6)$$

The optimal extent of plural sourcing is thus given by

$$\rho^* = x^* y^* = \frac{1}{4} - \left[\frac{\delta}{2(s + \theta)} \right]^2$$

These expressions capture the intuition that when $\delta = (b - m) > 0$, i.e., when there is a scale independent cost advantage to internal procurement, then in fact the majority of procurement will be

⁵We later expand on the conditions under which this assumption may be inappropriate.

internal ($x^* > \frac{1}{2}$), though a corner solution will not be reached because of the presence of complementarities $\theta > 0$ and constraints $s > 0$. In other words, plural sourcing results when

$$s + \theta > \delta > -(s + \theta) \quad (7)$$

or to write this in terms of the two different constraints, when

$$(i + \theta) > \delta > -(e + \theta) \quad (8)$$

or else we obtain corner solutions (all make or all buy).

From Equations (2 and (3, it

is clear that in the absence of complementarity and constraints (i.e., $e = i = k_1 = k_2 = 0$), x^* is

always a corner solution with $x^* = 1$ if $\delta > 0$, and $x^* = 0$ if $\delta < 0$. This corresponds to the basic

transaction cost injunction—produce internally in the presence of transactional hazards (i.e., $\delta > 0$)

or else buy. From Equation

(7, it is equally clear that the mere

presence of complementarities and constraints is insufficient to encourage plural sourcing. Unless the

nonlinearities in the total cost of inputs created by constraints and complementarities (s, θ) are strong

relative to the magnitude of δ —we always obtain corner solutions—all make or all buy. However,

with strong nonlinearities (as captured in Equation (7), we obtain plural

sourcing. Since $i > 0, e > 0, \theta > 0$, when $\delta > 0$, the critical condition is $(i + \theta) > \delta$, and when

$\delta < 0$, then the critical condition is $\delta > -(e + \theta) \Rightarrow (e + \theta) > |\delta|$. Lastly, strong complementarities

or strong constraints are individually sufficient to encourage plural sourcing (i.e., the conditions in

Equation (8 can be satisfied even when $\theta = 0$ or $i, e = 0$. We state

this as a proposition:

Proposition 1: Plural sourcing is optimal when either the complementarity or constraint effects (or both) are strong relative to the effect of transactional hazards.

This proposition captures the fundamental idea that an optimal level of plural sourcing balances the effects of complementarities and constraints (which push towards plural sourcing) against the effect of transactional hazards (which push towards pure sourcing).

Next we investigate possible biases in estimates of the relationship between transactional hazards and vertical integration when complementarities and constraints are ignored, or a case of plural sourcing is dichotomized into a pure sourcing strategy (e.g., greater than 80% volume made internally is coded as “make”). We take as the baseline the existence of transactional hazards ($\delta > 0$),

which indicates a bias towards vertical integration ($x^* > \frac{1}{2}$ from Equation (6)). This helps us state our results in the intuitive terms of “how complementarities and constraints influence the relationship **Q4** between transactional hazards and the extent of vertical integration.” Note that while we discuss transaction hazards, the argument applies to any factors that create a sourcing advantage for internal over external supply (such as interdependence, information asymmetry, or measurement uncertainty).

Taking the appropriate derivative, we get:

$$\frac{\partial^2 x^*}{\partial \delta \partial \theta} = \frac{-1}{2(s + \theta)^2} < 0 \quad (9)$$

This result shows that complementarities weaken the marginal effect of transactional hazards on the extent of internal sourcing. To see why this should be the case, consider that an optimal choice will balance the gains from procuring from the more efficient mode on a per unit basis (say internal

sourcing) against the complementarity with external procurement. Within the model, an increase in the magnitude of complementarity will therefore have to be met by an increase in the magnitude of transactional hazards to maintain the balance at the equilibrium level of internal sourcing. Therefore, for higher levels of complementarity, a higher level of transactional hazard is necessary to evoke the same optimal choice of internal sourcing levels. Thus, as the level of complementarities increase, the marginal effect of transactional hazards on the extent of internal sourcing declines. Thus, complementarities (which can arise either from knowledge or incentive considerations) negatively moderate the effect of transactional hazards on the extent of internal sourcing (i.e., vertical integration).

The effect of constraints on the relationship between transactional hazards and the extent of vertical integration can be shown to be similar. Taking the appropriate derivative, we get:

$$\frac{\partial^2 x^*}{\partial \delta \partial s} = \frac{-1}{2(s + \theta)^2} < 0 \quad (10)$$

Constraints, like complementarities, weaken the relationship between transactional hazards and the extent of internal procurement. Finally, note that Equations (9 and

(10 can be rewritten as:

$$\frac{\partial^2 x^*}{\partial (-\delta) \partial s} = \frac{\partial^2 x^*}{\partial (-\delta) \partial \theta} = \frac{1}{2(s + \theta)^2} > 0 \quad (11)$$

Thus, while complementarities and constraints weaken the positive association between transactional hazards and the level of vertical integration, they also weaken the *negative* association between volume independent factors that favor external procurement and the extent of internal sourcing.

Put differently, in the presence of complementarities and constraints, firms will make less than one would expect purely from transaction hazard considerations, and would make more internally than one would expect purely from considerations of volume independent cost advantages to external

procurement. Thus, to the extent that there are complementarities across internal and external procurement modes, arising from knowledge or incentive considerations, then transactional hazards may appear to have limited or no effects on the extent of vertical integration. Similarly, to the extent there are constraints such as limits to scale and barriers to exit, then transactional hazards may again appear to have limited or no effects on the extent of vertical integration.⁶ We formalize this as follows:

Proposition 2: When complementarities and/or constraints are omitted variables, we can expect a conservative bias in estimating the relationship between transaction hazards (such as asset specificity and/or demand uncertainty) and the optimal extent of vertical integration.

DISCUSSIONS AND CONCLUSIONS

Q5

Our analysis of optimal plural sourcing strategies has implications for both theory and empirical analyses of sourcing strategies.

Implications for theory

Our analysis offers a closer look at the assumption of mutual exclusivity of sourcing modes implicit in the phrase “make or buy.” Building on prior work on plural organizational forms (Bradach, 1997; Bradach and Eccles, 1989) and the benefits of plural sourcing (Porter, 1980; Harrigan, 1986; Parmigiani, 2007; Jacobides and Billinger, 2006), we proposed an integrated framework to explain how complementarities and constraints encourage plural sourcing and shape the optimal mix of internal and external sourcing. Our analysis suggests that while factors that confer a cost or benefit

⁶Interestingly, the bias becomes weaker as the magnitude of complementarities and constraints increase (Equations (9 and (10).

advantage to one of the modes of procurement (such as transactional hazards) push towards a pure sourcing model, constraints push firms away from corner solutions while complementarities pull towards equal usage of the two sourcing modes. The combination of these forces determines the optimal mix of internal and external sourcing, as set out in Equations

(4 and (5). Our analysis thus offers an analytical basis for explaining not only why and when firms optimally make and buy (Proposition 1), but also how much they make and buy.

The theory developed in this paper complements traditional transaction cost theorizing, or indeed any other theory that treats make or buy as mutually exclusive options, by specifying the conditions under which firms make and buy as well as how the optimal mix varies. Critically, the framework we provide enables predictions about the extent of vertical integration (i.e., the fraction of an input's requirements met internally—see Equations (4 and (5)—something that prior theory was not configured to address, focused as it was on whether a transaction was conducted internally or externally.

Perhaps the single most important insight to arise from a consideration of plural sourcing is the value of systemic analysis (e.g., at the level of a bundle of transactions, or at the level of the downstream business unit conducting the transactions) as opposed to individual transactional level analysis. Our arguments have been developed from the perspective of a sourcing firm that is considering choices about how much to make and buy, rather than a transaction level analysis about whether to make or buy an input. Shifting the level of analysis in this way leads to different predictions about transaction level choices. In the first place, it is possible to specify when multiple modes are used at all, as well as the extent being sourced from each mode.

More important, this also leads to predictions about the optimal levels of sourcing from each mode that are different from those generated by a consideration of transactional hazards or similar

factors alone. As we have noted, in the presence of complementarities and constraints, firms should be optimally less responsive to transactional hazard considerations in choosing the extent of internal procurement (Proposition 2). We thus see our analysis as being one of the steps towards moving from transaction level strategy to an analysis of the portfolio of sourcing options, which may also be closer to the realities of managerial practice (Bradach and Eccles, 1989; Jacobides and Billinger, 2006). Indeed, this is a move that Williamson has himself urged when calling on developments that extend analysis to looking at “the transaction in its entirety” (Williamson, 1985).

Our analysis also suggests several fruitful areas for further research. In the interests of simplicity, we have focused on plural sourcing with only two pure alternatives—make and buy. However, it seems feasible to extend the logic of our discussion to cases where a third alternative—alliance—is included. The precise mix of procurement volume across make, buy, and ally would be somewhat harder to evaluate, as a continuum with two poles now becomes tripolar; but the basic logic should remain similar. For instance, the comparative cost-benefit logic might indicate a more hierarchical mode of governance as asset specificity increases. The existence of knowledge or incentive complementarities should, however, cause firms to “distribute” their procurement across other modes as well, as would constraints. On the other hand, an analysis of two modes of procurement, such as make and ally, would be easily accommodated within our existing model with a simple relabeling.

It is also worth noting that the drivers of plural sourcing are distinct from those that motivate the selection of hybrids (such as alliances) over spot-market relationships and hierarchies. Within the transaction cost framework, hybrids become attractive relative to the poles for intermediate levels of transactional hazards (Williamson, 1991a; Gulati *et al.*, 2005). However, plural sourcing does not lie intermediate between making and buying—it instead involves both. Intermediate levels of transactional hazards, therefore, cannot explain plural sourcing though they may explain the preference

for hybrids. Conversely, complementarities or constraints cannot explain the preference for hybrids—which have governance characteristics intermediate between internal and external procurement. The drivers of plural sourcing and of the choice of hybrid governance forms should, therefore, be distinct. This is a proposition that suggest a fruitful line of theory development and empirical investigation.

Our analysis also points to interesting linkages between procurement decisions and strategic actions such as preempting entry or diversification—whereas these two classes of decisions are rarely viewed together. The linkage exists because of constraints and complementarities—to the extent investment in excess capacity or diversification influences the constraints on internal or external procurement, such strategies may also influence procurement strategies, creating a tendency towards plural sourcing.

Implications for empirical analysis

We have introduced two new categories of variables in our analysis of plural sourcing strategies—complementarities and constraints (in addition to well established concepts such as transactional hazards). To make our ideas amenable to empirical analysis, we provide suggestions on how to measure these variables in Table 1. To the extent we can assume optimizing behavior by decision makers, our model provides predictions about sourcing strategies we are likely to observe in data.⁷ It should therefore be possible to empirically test our arguments both on when plural sourcing occurs

⁷Alternatively, managers might choose a particular sourcing strategy based on a variety of reasons unconnected with the theory—yet only those decisions that are “appropriate” given the levels of complementarities and constraints will perform well (and hence be observed) in the face of adequate competitive selection pressures. In other words, if managers make poor governance choices for their exchange relationships, such relationships will perform poorly relative to competition, and may not survive (Williamson, 1985).

(Proposition 1) as well as the mix of internal and external sourcing employed (Equations

(4 and (5).

However, even scholars interested in issues of vertical integration (and not necessarily plural sourcing) will also find something of value in our results. We investigated whether the omission of complementarities and constraints in empirical tests of the relationship between transactional hazards and the extent of vertical integration would generate any biases. Within our model, we find a bias does exist, but it is a conservative one (Proposition 2)—to the extent a positive association is found, it is likely to be genuine.

Further, suppose we were now to dichotomize x^* at some level of vertical integration v such that $x^D = 1$ if $x^* > v$ and $x^D = 0$ if $x^* \leq v$. In a standard discrete choice model (such as logit or probit), x^* now serves as an underlying latent variable. As long as an increase in δ results in an increase in x^* , it will also be associated positively with the likelihood of $x^D = 1$. As we have just shown, omitting complementarities and/or constraints only creates a conservative bias in estimated relationships between δ and x^* , and this same conservative bias will also be inherited in a specification that dichotomizes x^* as above. Thus, while complementarity and constraints are necessary to understand when plural sourcing is optimal and what the mix of internal and external sourcing should be, ignoring these factors only generates a conservative bias in studies concerned with explaining vertical integration (either as a continuous or dichotomous variable) as a function of transaction hazards.

In our analysis, we have drawn on prior research to focus on complementarities—situations in which sourcing in one mode enhances the value of sourcing from the other. However, it is theoretically possible that the interaction is one of substitution—where procurement from the internal supplier in fact decreases the marginal value of procurement from the external supplier—though such instances

have not yet been systematically studied empirically. The formal analysis we conducted is, however, easy to modify for such possibilities. A key insight is that in the case of substitutive interactions between sourcing modes (e.g., the use of external procurement demotivates internal suppliers instead of spurring competition and enhanced incentives for them), ignoring such interactions can create an upward bias in empirical estimates of the strength of the relationship between transactional hazards and internal sourcing.

LIMITATIONS AND CONCLUSIONS

Our study is not without limitations, which arise partly from the features of the methodology we use—analysis of a formal optimization model. When working with a formal as opposed to a verbal model, we are subject to the same trade-off between realism and rigor that applies to all models. However, formal models such as the one we use in this paper merely highlight the trade-off more sharply—they accentuate the benefits of clearly stating assumptions, and can generate nonintuitive insights (Lave and March, 1993). For instance, the model helped us see that complementarity and constraints, while necessary, must be large relative to transactional hazards to make plural sourcing optimal (Proposition 1); also, that they create a conservative bias when omitted in empirical work (Proposition 2). On the other hand, the assumptions that underlie models such as ours also appear unrealistic (full information on parameters, optimization, etc.). As with all formal analysis, we also hope that the simplifying assumptions of our model are justified by the fact that it provides a rigorous basis for improving our understanding of a complex phenomenon, and generates interesting and testable predictions. We may also think about our results as pertaining to theoretically optimal sourcing strategies, and either study the empirical conditions under which managerial choices approach these, or alternately consider these to be normative benchmarks.

In the interests of tractability, we have also chosen to define the scope of our model fairly narrowly. Rather than model the *mechanisms* that generate complementarities or constraints (e.g.,

knowledge transfer, competition between internal and external suppliers, hold-up, administrative diseconomies of scale, etc.), we have opted to take these mechanisms as given and captured in a reduced form by parameters in the model. Instead, our focus has been on the optimal choice of internal and external sourcing that would result from “farsighted contracting” decisions made by a decision maker with full information on these parameters (Williamson, 1990). However, some of these mechanisms could clearly benefit from an independent formal treatment in their own right—such as knowledge complementarities, or administrative diseconomies of scale—an activity we defer for future research.

Despite these limitations, we believe our research makes an important contribution to the literature on organizational form and procurement modes. By providing a theoretical framework to explain the occurrence and extent of plural sourcing, we extend existing theory and also bring a phenomenon that has often been treated as “noise” surrounding make or buy decisions into the domain of systematic analysis. In some of the early work on this topic, Bradach and Eccles noted that “explanations for when and why different mixtures of control mechanisms occur need to be developed. Such explanations may end up consistent with existing theories such as transaction cost economics. Little progress will be made, however, unless we step away from the theoretical baggage which insists that we view markets and hierarchies as mutually exclusive alternatives” (1989: 116). It is heartening to notice that the topic of plural sourcing has begun to attract scholarly attention again (He and Nickerson, 2006; Parmigiani, 2007; Jacobides and Billinger, 2006) after a long hiatus (Porter, 1980; Harrigan, 1985; Bradach and Eccles, 1989). Yet much undoubtedly remains to be done. We hope to have contributed towards developing a rigorous, integrated theoretical foundation for making further progress on the fascinating question of why firms both make and buy.

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TECHNICAL APPENDIX

General formulation of model and its properties

The optimization problem can be written as

$$\underset{x,y}{\text{Minimise}} C(x,y) \text{ s.t. } x+y=k>0, x\geq 0, y\geq 0$$

Here, x is the amount made in-house and y is the amount bought from an external source, and $C(x,y)$ is the total cost of sourcing, which is to be minimized. We assume that $C(x,y)$ is strictly increasing in each of its arguments, keeping the other constant, is continuously differentiable to the second order in

each argument, and is strictly quasi-convex. Moreover, for any x , $\frac{\partial C(x,0)}{\partial y} = \infty$, and, similarly, for any

y , $\frac{\partial C(0,y)}{\partial x} = \infty$. These assumptions guarantee both the existence and the uniqueness of an interior solution.

It is easy to show that the equilibrium occurs at (x^*, y^*) where the following condition is

$$\text{satisfied: } \frac{\partial C(x^*, y^*)}{\partial x} = \frac{\partial C(x^*, y^*)}{\partial y} \quad (\text{A.1})$$

We normalize $k = 1$ so that x, y become the proportions made and bought, respectively, and

$$y^* = 1 - x^*.$$

We will first state a general result that can be used to examine the specific effects of complementarity and constraints. Consider a parameter t of the function $C(x,y)$ and its effect on the equilibrium x^* : Assume that $C(x,y,t)$ is continuously differentiable in t .

Differentiating the identity $\frac{\partial C(x^*, y^*, t)}{\partial x} = \frac{\partial C(x^*, y^*, t)}{\partial y}$ with respect to t , we get

$\frac{\partial^2 C}{\partial x^2} \frac{dx^*}{dt} + \frac{\partial^2 C}{\partial y \partial x} \frac{dy^*}{dt} + \frac{d}{dt} \left(\frac{\partial C}{\partial x} \right) = \frac{\partial^2 C}{\partial x \partial y} \frac{dx^*}{dt} + \frac{\partial^2 C}{\partial y^2} \frac{dy^*}{dt} + \frac{d}{dt} \left(\frac{\partial C}{\partial y} \right)$, where the second derivatives are taken at (x^*, y^*, t) .

Since $x^* + y^* = k$, we can write $\frac{dy^*}{dt} = -\frac{dx^*}{dt}$. So, we have:

$$\frac{dx^*}{dt} = \frac{\frac{d}{dt} \left(\frac{\partial C}{\partial x} \right) - \frac{d}{dt} \left(\frac{\partial C}{\partial y} \right)}{-\left[\frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial x^2} - 2 \frac{\partial^2 C}{\partial x \partial y} \right]} \quad (\text{A.2})$$

By quasiconvexity, the denominator is negative.

Lemma 1

The sign of $\frac{dx^*}{dt}$ depends on the sign of $\frac{d}{dt} \left(\frac{\partial C}{\partial x} \right) - \frac{d}{dt} \left(\frac{\partial C}{\partial y} \right)$; whether x^* increases or decreases with t depends on whether the numerator of Equation (A.2) is negative or positive.

Note that this expression is the derivative with respect to the parameter t of the difference between the marginal cost of internal sourcing and marginal cost of external sourcing.

Definitions: constraints and complementarities

Within this framework, we can now define constraints and complementarities.

Denote the marginal rate of transformation by $MRT_{x,y} \equiv \frac{C_x(x,y)}{C_y(x,y)} \equiv \frac{\frac{\partial C(x,y)}{\partial x}}{\frac{\partial C(x,y)}{\partial y}}$.

Consider three parameters i , e , and θ that govern the form of the function $C(x,y)$, such that $MRT_{x,y}$ is differentiable in each parameter, and

- $MRT_{x,y}$ is strictly *decreasing* in e for all x in $(0, k)$,
- $MRT_{x,y}$ is strictly *increasing* in i for all x in $(0, k)$,

- $MRT_{X,Y}$ is *decreasing* with respect to θ up until some $x^0 \in (0, k)$, and is *increasing* with respect to θ for $x > x^0$.

Then, i is a *constraint on internal sourcing*, e is a *constraint on external procurement*, and θ denotes the *complementarity* between internal and external sourcing.

To show the intuition, note that at (x^*, y^*) ,

$$\frac{d}{dt}MRT_{x,y} = \frac{1}{(C_y)^2} \left(C_y \frac{dC_x}{dt} - C_x \frac{dC_y}{dt} \right) = \frac{1}{C_y} \left(\frac{dC_x}{dt} - \frac{dC_y}{dt} \right), \text{ since } C_x = C_y.$$

Since the denominator of Equation (A.2 is negative, $\frac{dx^*}{dt}$ has the opposite

sign as $\frac{d}{dt}MRT_{x,y}$.

From Equation (A.2, we can write $\frac{dx^*}{dt} = \frac{C_y \frac{d}{dt}MRT_{xy}}{-\left[\frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial y^2} - 2\frac{\partial^2 C}{\partial x \partial y}\right]}$. Since

the denominator is negative, the sign of dx^*/dt is opposite of the sign of the derivative of MRT_{XY} .

Thus, we have $\frac{dx^*}{di} < 0$, which makes i a constraint on production. Similarly, we have $\frac{dx^*}{de} > 0$ or

$\frac{dy^*}{de} = -\frac{dx^*}{de} < 0$, which makes e a constraint on procurement. On the other hand, for $x^* < x^0$, $\frac{dx^*}{d\theta} > 0$

and for $x^* > x^0$, $\frac{dx^*}{d\theta} < 0$. Thus, an increase in θ “pulls” the optimum towards some interior

allocation—i.e., makes combinations of making and buying superior to doing either alone.

Robustness of Proposition 2 to combining internal and external constraints

Since we have assumed $e = i = s$, any comparative static result using s assumes that not only both constraints are equally strong, but also that they are being increased equally. However, we show below that even if only one of the constraints increases, Proposition 2 still holds.

$$x^* = \frac{e + \theta + \delta}{e + i + 2\theta}$$

This implies that $\frac{\partial x^*}{\partial \delta} = \frac{1}{e + i + 2\theta}$.

Therefore, $\frac{\partial^2 x^*}{\partial \theta \partial \delta} = -\frac{2}{(e + i + 2\theta)^2} < 0$. Also, $\frac{\partial^2 x^*}{\partial e \partial \delta} = \frac{\partial^2 x^*}{\partial \delta \partial e} = -\frac{1}{(e + i + 2\theta)^2} < 0$.

Thus, Proposition 2 holds irrespective of the levels of e and i . In particular, the result does not depend on the assumption that they are equal to some number s .

Figure 1. Governance costs as a function of asset specificity

Table 1. Complementarities and constraints: an overview

Concept	Key mechanism	Manifestations	Suggested measurement of concept
Incentive complementarities	Competition	Threat of backward integration/outsourcing, superior information on costs/prices and performance measurement, benchmarking and “ratcheting” of performance	Incentive complementarities should be stronger when the measurement of production efforts/ costs is difficult
Knowledge complementarities	Collaboration	Distinct kinds of innovation by internal and external suppliers	Knowledge complementarities should be stronger for relatively novel production technologies—where much remains to be learned about optimal production

Constraints: limits to scale	Scale diseconomies	Coordination complexity and weakened incentives	Constraints to internal production should be stronger for larger firms and for firms with high current levels of administrative expenses
			Constraints to internal production could also exist when there is significant volume uncertainty coupled with high cost of excess capacity
Constraints: barriers to exit	Lock-ins	Commitment/reputation lock-ins Bargaining power of unions	Constraints to external sourcing should be stronger in settings where unions have greater bargaining power, where the internal unit has been in existence for a long period of time, and where government regulations make divestment/downsizing more difficult.

2063 Author Queries

Q1 Please confirm insertion of words or complete the sentence.

Q2 Italics removed on “k” to comply with the figure.

Q3 Should the “c” in this parameter be uppercase as in the EQ1 or lowercase as in EQ2. It’s uppercase in the Technical Appendix. Please provide new values/equations if necessary. Also, on the previous page and in the Technical Appendix, “minimise” appears in an equation. This journal uses American spelling (minimize) – would you like to provide a new equation or leave it as is? I am unable to change the equations as they are sealed units.

Q4 Please provide a citation for this quotation if applicable. Or perhaps the quotation marks are unnecessary?

Q5 Conclusions as a main heading occurs again later on – OK to delete here?